SECTION 349
CONCRETE CURING

349.1 GENERAL

The work covered in this section consists of furnishing all plant, labor, materials, and equipment, and in performing all operations in connection with the curing of all concrete placed in accordance with these specifications, or as modified by the plans and/or the Supplemental Specifications, and as authorized by the ENGINEER.

349.2 REFERENCES

349.2.1 American Society for Testing and Materials (Latest Editions)(ASTM)

C-31 Making and Curing of Concrete Test Specimens in the Field

C-39 Test for Compressive Strength of Cylindrical Concrete Specimens

C-42 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C-171 Specification for Sheet Materials for Curing Concrete

349.2.2 American Concrete Institute (Latest Editions)(ACI)

ACI 305 Hot Weather Concreting
ACI 306 Cold Weather Concreting

349.2.3 This Publication:

Section 105	Concrete Curing Compound
Section 111	Colored Portland Cement Concrete

349.3 CURING

Curing is defined as the process of maintaining a satisfactory moisture content and temperature in the constructed concrete so that the specified compressive strength is attained before the concrete is placed into full service. The curing process starts with the concrete placement.

349.4 PLACEMENT

349.4.1 The placement of all concrete shall be in accordance with the following guidelines unless otherwise authorized by the ENGINEER.

349.4.1.1 Concrete shall not be placed on frozen ground nor in forms that have frost, snow, or ice in or on the forms, reinforcement and/or embedment items.

349.4.1.2 Concrete shall not be placed in standing or running water.

349.4.1.3 Concrete shall not be placed on mud or uncompacted subgrade. Unstable subgrade shall be removed and replaced with suitable, compacted material.

349.4.1.4 Concrete shall not be placed in wooden forms that have not been sealed or treated with form oil or a form release agent.

349.4.1.5 The subgrade on which concrete is to be placed shall be moistened immediately before the concrete is placed.

349.5 MOISTURE CONTROL

349.5.1 The CONTRACTOR shall minimize the loss of moisture from the plastic concrete by evaporation during the placement and finishing of the concrete. When the estimated evaporation rate, as determined from Chart 349.1 is greater than 0.20 lb/sf/hr., the CONTRACTOR shall either take steps to reduce the evaporation below the specified rate, or discontinue the placement. The CONTRACTOR shall confer with the ENGINEER when weather conditions are such that the specified evaporation rate is reached on the protection method he is planning to use to be able to continue the placement of the concrete.

349.5.2 Moisture shall not be applied to the surface of the concrete to aid the surface finishing. If plastic or surface shrinkage cracks develop either prior to or during the finishing, that concrete shall be removed and replaced.

349.5.3 After completion of the finishing of the concrete, the CONTRACTOR shall initiate immediately the final curing of the concrete. The final curing method used by the CONTRACTOR shall be as specified in this section and as approved by the ENGINEER.

349.5.4 When forms are removed prior to the completion of the curing period specified herein, the CONTRACTOR shall protect the formed concrete surfaces by the same curing method used on the exposed surfaces of the concrete.

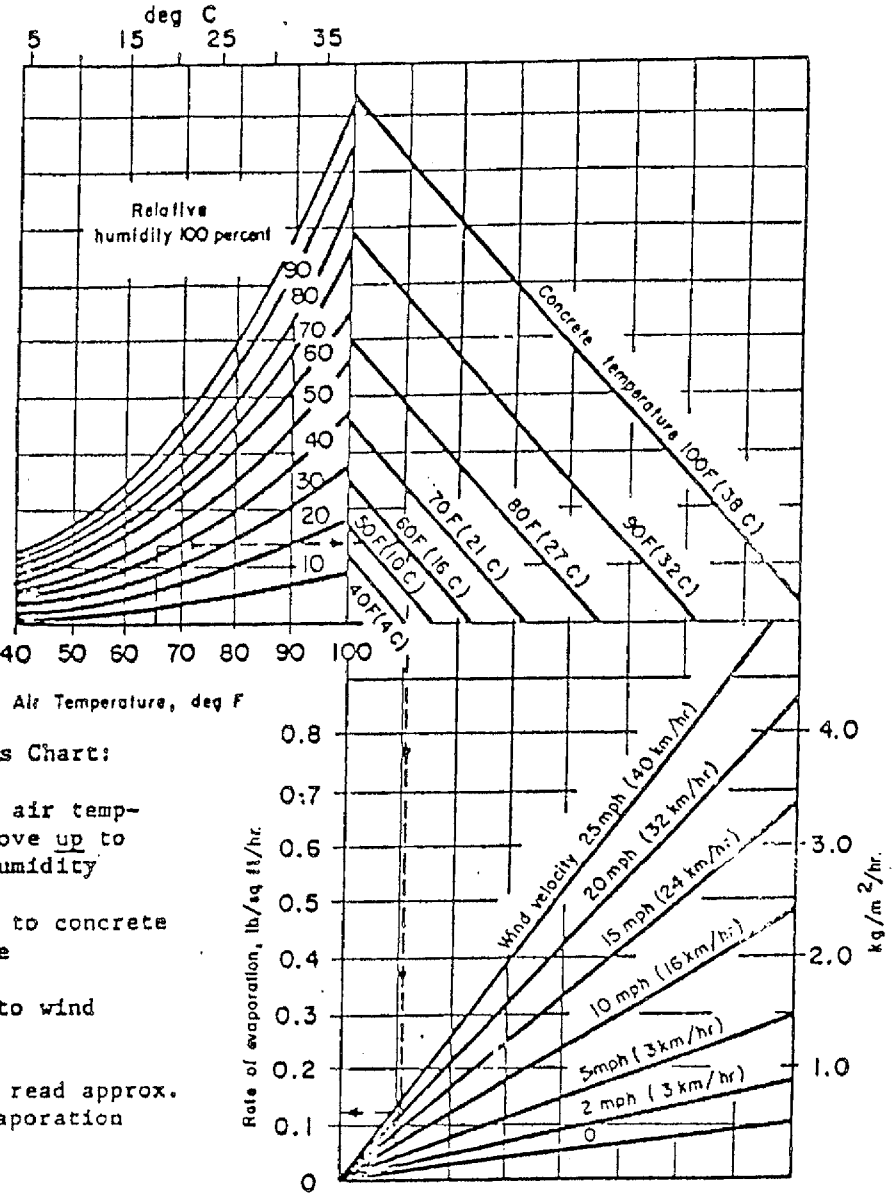
349.6 TEMPERATURE CONTROL

349.6.1 The temperature of all concrete placed shall be a minimum of 50°F(10°C) and a maximum of 90°F (32.2°C). The water, aggregates, and sand can be heated to maintain the minimum temperature and ice can be used to replace some of the water to maintain the concrete under the maximum temperature as long as the specified water to cementitious material ratio is not exceeded.

349.6.2 After completion of the finishing of the concrete, the CONTRACTOR shall initiate immediately the final curing of the concrete. Temperature control during and for the duration of the curing period is essential to provide a satisfactory temperature to assure hydration of the portland cement to achieve the specified compressive strength of the concrete.

CHART 349.1

EVAPORATION RATE



To Use This Chart:

1. Enter with air temperature, move up to relative humidity
2. Move right to concrete temperature
3. Move down to wind velocity
4. Move left; read approx. rate of evaporation

Effect of concrete and air temperatures, relative humidity, and wind velocity on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. To use the chart, follow the four steps outlined above. If the rate of evaporation approaches 0.2 lb per sq ft per hr (1.0 kg/m^2/hr), precautions against plastic shrinkage cracking are necessary.

349.6.2.1 During cold weather, the CONTRACTOR shall maintain the temperature of all newly constructed concrete at not less than 50°F (10°C) for the curing period by the use of insulated blankets, an outside heating source, or other methods approved by the ENGINEER.

349.6.2.2 During hot weather, the CONTRACTOR may find it necessary to cover or shade newly constructed concrete to reduce the temperature build up and moisture loss (flash setting) in the concrete.

349.6.3 The ENGINEER shall monitor and record the high and low temperature of the concrete for every 24-hour period during the curing period when temperature protection is used by the CONTRACTOR, or at intervals deemed necessary by the ENGINEER. High-low thermometers or other temperature monitoring/recording systems may be used by the ENGINEER. The ENGINEER will notify the CONTRACTOR when the temperature of the newly constructed concrete reaches a low temperature of 53°F (11.7°C) or a high temperature of 100°F (37.8°C) so that the CONTRACTOR can modify his method of curing to maintain the proper curing temperature.

349.7 CURING METHODS

349.7.1 Immediately after the finishing operation has been completed and as soon as marring of concrete will not occur, the CONTRACTOR shall initiate the final curing of the concrete by one (1) or a combination of the following methods or a method the CONTRACTOR has submitted and received authorization from the ENGINEER to use.

349.7.1.1 Curing Compound: All curing compounds used shall be in accordance with Section 105 or Section 111 if applied to colored concrete.

349.7.1.2 Waterproof Paper: Waterproof paper shall comply with ASTM C-171. The Paper shall be new and unused. The paper shall be placed so as to cover the entire area of concrete plus two (2) feet in all directions, with an 18" overlap at each joint and be weighed down at all joints and along all edges. Any area that is damaged during the curing period shall be repaired or replaced the same day.

349.7.1.3 Plastic Film - Polyethylene Sheeting: The sheeting shall be a minimum of 4 mils thick; clear, white or black and comply with ASTM C-171. The sheeting shall be placed in the same manner as the waterproof paper. Black sheeting should only be used when there is a need to retain heat in the new concrete.

349.7.1.4 Ponding, immersion, fog spraying, or sprinkling: Any one of these four (4) curing methods can be used directly on the new concrete surface only when the CONTRACTOR submits to the ENGINEER as part of his curing program a plan that addresses these items:

A. Water source.
B. Equipment to be used and backup.
C. Plan to ensure continuous application of water throughout the curing period.
D. Protection against erosion of the concrete surface.
E. Disposal of the water used and protection of the supporting and surrounding areas.

These methods can only be used if approved by the EINGINEER.

349.7.1.5 Burlap, Cotton Mats, or Rugs: Burlap or other materials must be free of sizing or any substances that are injurious to portland cement or causes discoloration. The sections shall be lapped one-half (1/2) their width and 12" at each end. The sections shall be placed so as to extend two (2') feet beyond the edge of the concrete in all directions. The material shall be kept moist and not be allowed to become dry at any time during the curing period.

349.7.1.6 Earth or Sand: The use of earth or sand as a curing cover will not be permitted on any concrete placed in any channel. Earth or sand used as a curing cover shall have particles larger than one inch (1") and shall be free of any organic matter. Earth or sand shall be placed on the new concrete in a minimum thickness of two inches (2") and extend one foot (1') beyond the edge of the concrete. The earth or sand shall be kept moist and not be allowed to become dry at any time during the curing period.

349.7.1.7 Straw or Hay: The use of straw or hay as a curing cover will not be permitted on any concrete placed in any channel. Straw or hay shall be placed on the new concrete in a minimum thickness of six inches (6") and held in place by wire or a cover to protect against the wind relocating the material. The straw or hay shall be kept moist and not be allowed to become dry at any time during the curing period.

349.8 CURING PERIOD

349.8.1 It is the CONTRACTOR'S responsibility to place and cure all concrete in a manner that will ensure that the specified concrete strength is reached. The curing period that is required for a particular volume of concrete will depend on the concrete mix that is placed, the location that it is placed in, how the CONTRACTOR controls the moisture loss and temperature in the concrete, and the weather conditions during placement and curing. The CONTRACTOR is responsible for providing active curing as

listed above and/or passive curing for any length of time that it takes for all constructed concrete to reach its specified strength.

349.8.2 The minimum active curing period for all construction concrete shall be based on minimum strength gained or Strength-Maturity Relations Analysis or minimum time table, whichever is the shortest, or as authorized by the ENGINEER.

349.8.2.1 Minimum Strength: Active curing may be discontinued when the average strength of two (2) field cured concrete cylinders or three (3) drilled cores is 85% or higher of the specified concrete strength.

349.8.2.1.1 The field cured cylinders shall be standard concrete cylinders molded in accordance with ASTM C-31, cured the same as the concrete they represent and tested in accordance with the requirements of ASTM C-39.

349.8.2.1.2 The drilled cores shall be sampled in accordance with ASTM C-42 and tested in accordance with the requirements of ASTM C-39, with no single core test strength being less than 75% of the specified concrete strength.

349.8.2.2 Strength-Maturity Relationship: The active curing may be discontinued at the end of the period defined by a Strength-Maturity Relationship Analysis prepared by a Registered Professional Engineer in accordance with ACI 306 and approved by the ENGINEER.

349.8.2.3 Minimum Time Table:

Weather	Min. Curing Days
Warm to Hot	10
Cold	14

Cold weather is defined as when the temperature reaches or goes below 35°F (1.7°C) for one (1) hour during any 24-hour period during the curing period.

349.9 SUBMITTALS:

When required in Section 1502 of the Supplemental Technical Specification or requested by the ENGINEER, the CONTRACTOR shall submit along with the concrete mix design(s) a curing plan for each strength and application of concrete on the project. The plan shall outline which curing method(s) the CONTRACTOR is proposing to use, where each method(s) will be used and the estimated period of active curing each location or type of structure will require.

349.10 MEASUREMENT AND PAYMENT

The measurement and payment for all materials, labor and equipment required in the curing process of the concrete constructed shall be included in the cost of the concrete to which it is applied. No separate measurement or payment will be made for concrete curing.